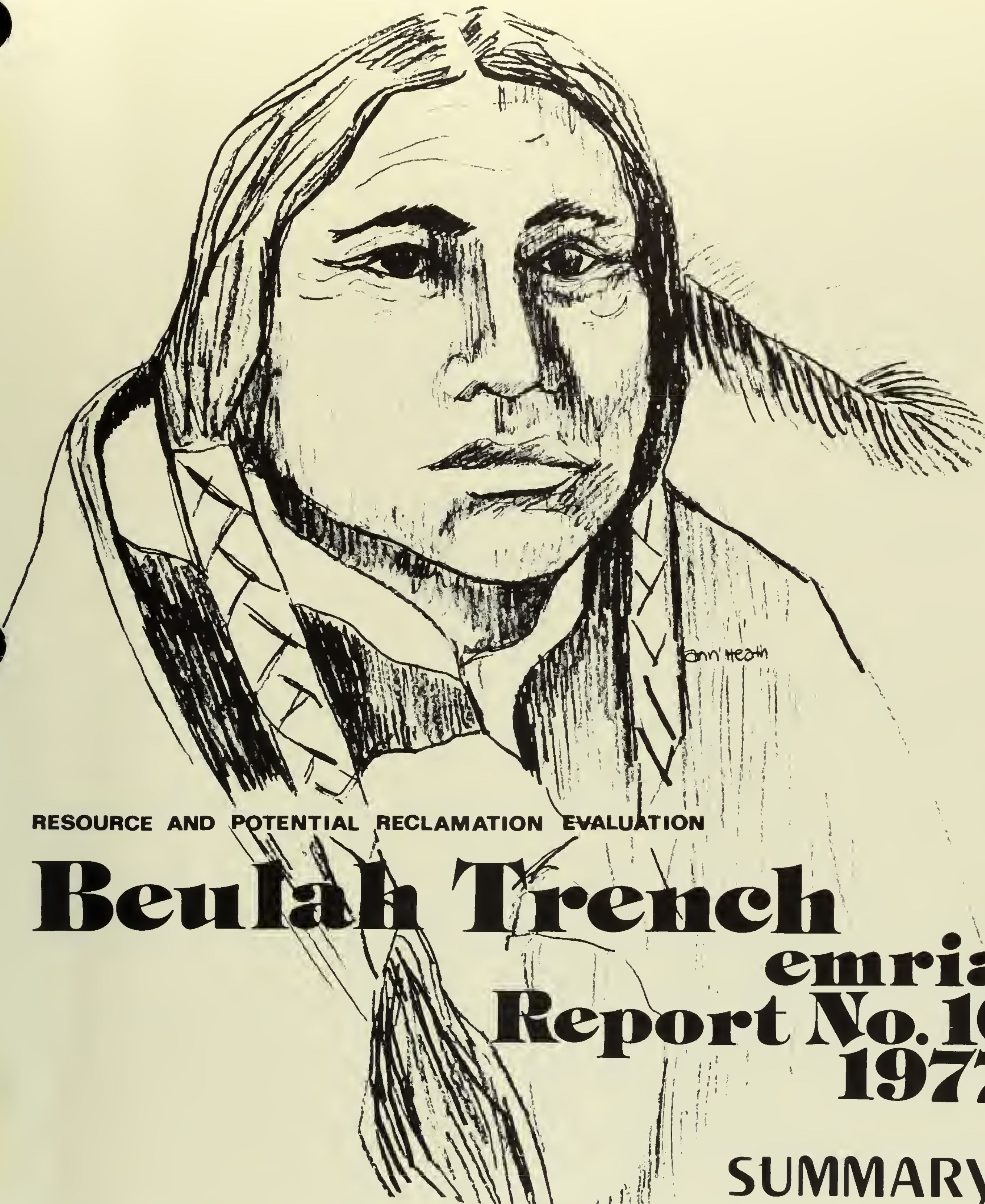


RESOURCE AND POTENTIAL RECLAMATION EVALUATION

Beulah Trench

emria Report No. 10 1977

SUMMARY

United States Department of the Interior
Bureau of Land Management
Water & Power Resources Service
Geological Survey

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD
MERCER COUNTY, NORTH DAKOTA

INTRODUCTION

Recent energy shortages have forced our society to seek new domestic sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior and, principally, the Bureau of Land Management to assist in meeting these energy demands and, at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, coal resources, overburden (soil and bedrock), greenhouse, vegetation, and hydrology. Less detailed information is provided on climate and physiography.

LOCATION

The Beulah Trench Study Area is located in Mercer County, North Dakota, approximately 5 miles northwest of Beulah (Plate 1). The area includes about 2700 acres in all or parts of sections 14, 22, and 26, T. 145 N., R. 88 W., and sections 4, 6, and 8, T. 144 N., R. 88 W. (Plate 2 and Photograph 1).

All coal in the study area is federally owned; however, all surface is privately owned (Plate 3).

CLIMATE

Climate in the Beulah Trench Study Area is characterized by warm summers, harsh cold winters, long periods of sunshine, and a moderate amount of precipitation during the growing season. Data recorded between 1955 and 1974 at Beulah, North Dakota, (approximately 5 miles southeast of the study area) were used to evaluate temperature, precipitation, and related climatic factors for the study area.

Temperature extremes of 104°F and -39°F are probable in this study area. The average annual temperature is 40.6°F. Frontal systems pass through the area frequently causing large, rapid fluctuations in temperature.

The growing season for hardy crops is estimated at 134 days between mid-May and mid-to-late September.1/ However, native range plants usually deplete the available soil moisture by mid-July and mature or become dormant.

1/ Includes days when the minimum temperature exceeds 28°F.

The average annual precipitation in this study area is about 16.13 inches, with nearly 75 percent of this amount occurring during the growing season. June is the wettest month, averaging 3.34 inches. Average snowfall for the area is about 27 inches.

The prevailing wind direction is west-northwesterly except in May, June, July, and August, when it is easterly. During April, the windiest month, the wind speed averages 13 miles per hour.

Thunderstorms and hail occur most frequently during June and July. Probable rainfall intensities vary from 1.1 inches in 30 minutes to 2.7 inches in 24 hours (1 year in 5).

The interaction of climate and aspect generally does not limit crop or range production in this area. The surface relief is relatively subdued and, although the south facing slopes are more droughty, the reduction in plant productivity is minimal.

Annual evaporation from both Class A pans and lakes is estimated at 36 inches.

The area receives about 60 percent of the sunshine that could possibly occur each year.

In general, most climatic factors in the Beulah Trench Study Area appear favorable for revegetation of surface-mined land. The spring rains usually provide moisture to the soil in excess of the plant moisture requirement. With favorable soil moisture, seedlings will grow rapidly and become established before the available moisture is depleted by about mid-July.

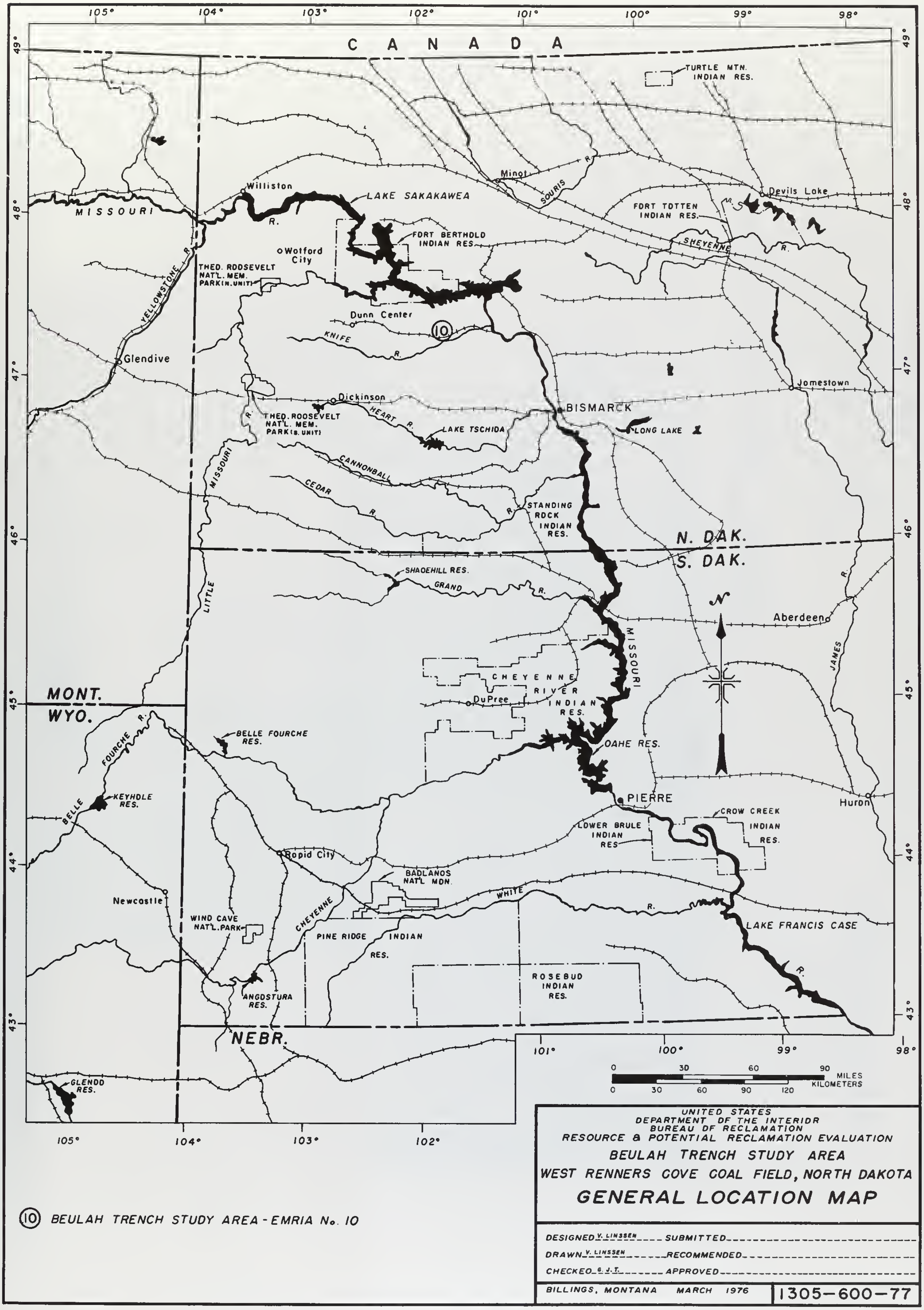
Climatic factors that may adversely affect revegetation efforts in this study area include: 1) below normal or uneven distribution of precipitation, especially during the growing season; 2) severe thunderstorms and/or strong winds that cause erosion; 3) late spring freezes; and 4) depletion of soil moisture by wind.

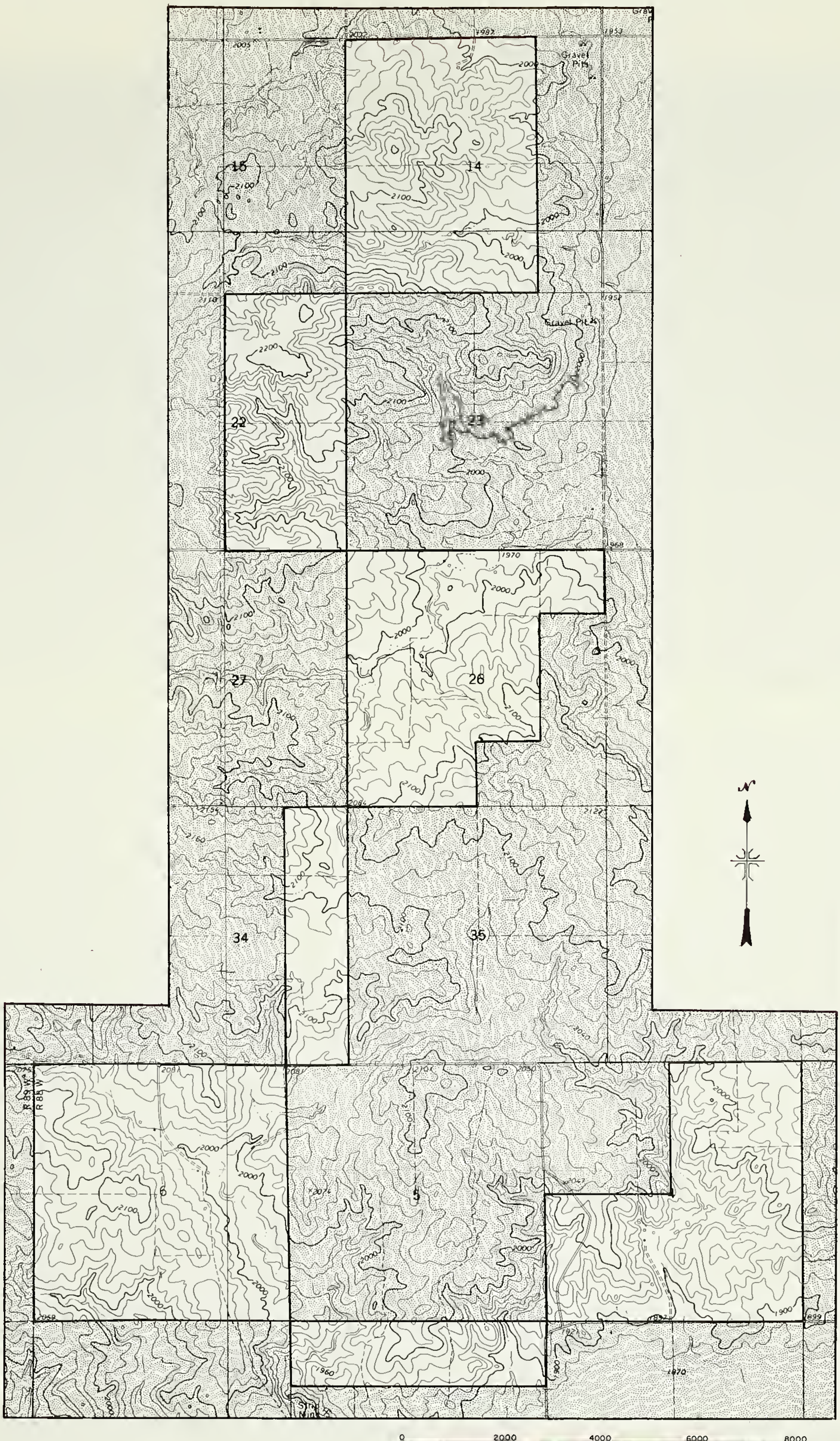
PHYSIOGRAPHY AND DRAINAGE

The Beulah Trench Study Area lies in the glaciated portion of the Great Plains Physiographic Province. The topography is characterized by rolling hills bordered on the east and south by wide, flat Pleistocene meltwater channels.

Maximum relief is about 340 feet, ranging from 2210 feet on hilltops in the northwestern portion of the study area to 1870 feet in the meltwater channel that crosses the southeast corner of the area.

Drainage in the study area is accomplished through a well developed dendritic system. The extreme northern end of the study area drains northward via the buried channel into Lake Sakakawea. The remainder of the study area drains southward into Spring Creek, a tributary of the Knife River.


CANADA
TURTLE MTN. INDIAN RES.
Minot
SOURIS R.
Devils Lake
FORT TOTTEN INDIAN RES.
SHEYENNE R.
Williston
LAKE SAKAKAWEA
MISSOURI R.
FORT BERTHOLD INDIAN RES.
Watford City
THEO. ROOSEVELT NAT'L. MEM. PARK (N. UNIT)
YELLOWSTONE R.
Dunn Center
10
KNIFE R.
Glendive
Jamestown
Dickinson
THEO. ROOSEVELT NAT'L. MEM. PARK (S. UNIT)
HEART R.
LAKE TSCHIDA
BISMARCK
LONG LAKE
LITTLE MISSOURI R.
CANNONBALL
CEDAR R.
STANDING ROCK INDIAN RES.
N. DAK.
S. DAK.
SHADEHILL RES.
GRAND R.
Aberdeen
JAMES R.
MISSOURI
CHEYENNE RIVER INDIAN RES.
DuPree
MONT.
WYO.
BELLE FOURCHE R.
BELLE FOURCHE RES.
OAHE RES.
KEYHOLE RES.
PIERRE
CROW CREEK INDIAN RES.
LOWER BRULE INDIAN RES.
Huron
Rapid City
BADLANDS NAT'L. MON.
Newcastle
WHITE R.
WIND CAVE NAT'L. PARK
CHEYENNE
PINE RIDGE INDIAN RES.
LAKE FRANCIS CASE
ROSEBUD INDIAN RES.
ANGOSTURA RES.
NEBR.
GLENDO RES.
105° 104° 103° 102° 101° 100° 99° 98°
49° 48° 47° 46° 45° 44° 43°
0 30 60 90 MILES
0 30 60 90 120 KILOMETERS
10 BEULAH TRENCH STUDY AREA - EMRIA No. 10
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COAL FIELD, NORTH DAKOTA
GENERAL LOCATION MAP
DESIGNED V. LINSSEN SUBMITTED
DRAWN V. LINSSEN RECOMMENDED
CHECKED G. J. T. APPROVED
BILLINGS, MONTANA MARCH 1976
1305-600-77



NORTH DAKOTA

QUADRANGLE LOCATIONS

PORTIONS OF U.S.G.S. BEULAH, BEULAH N.W., BEULAH N.E., & ZAP QUADRANGLES

0 2000 4000 6000 8000 FEET

0 400 800 1200 1600 2000 2400 METERS

CONTOUR INTERVAL — 20 FEET

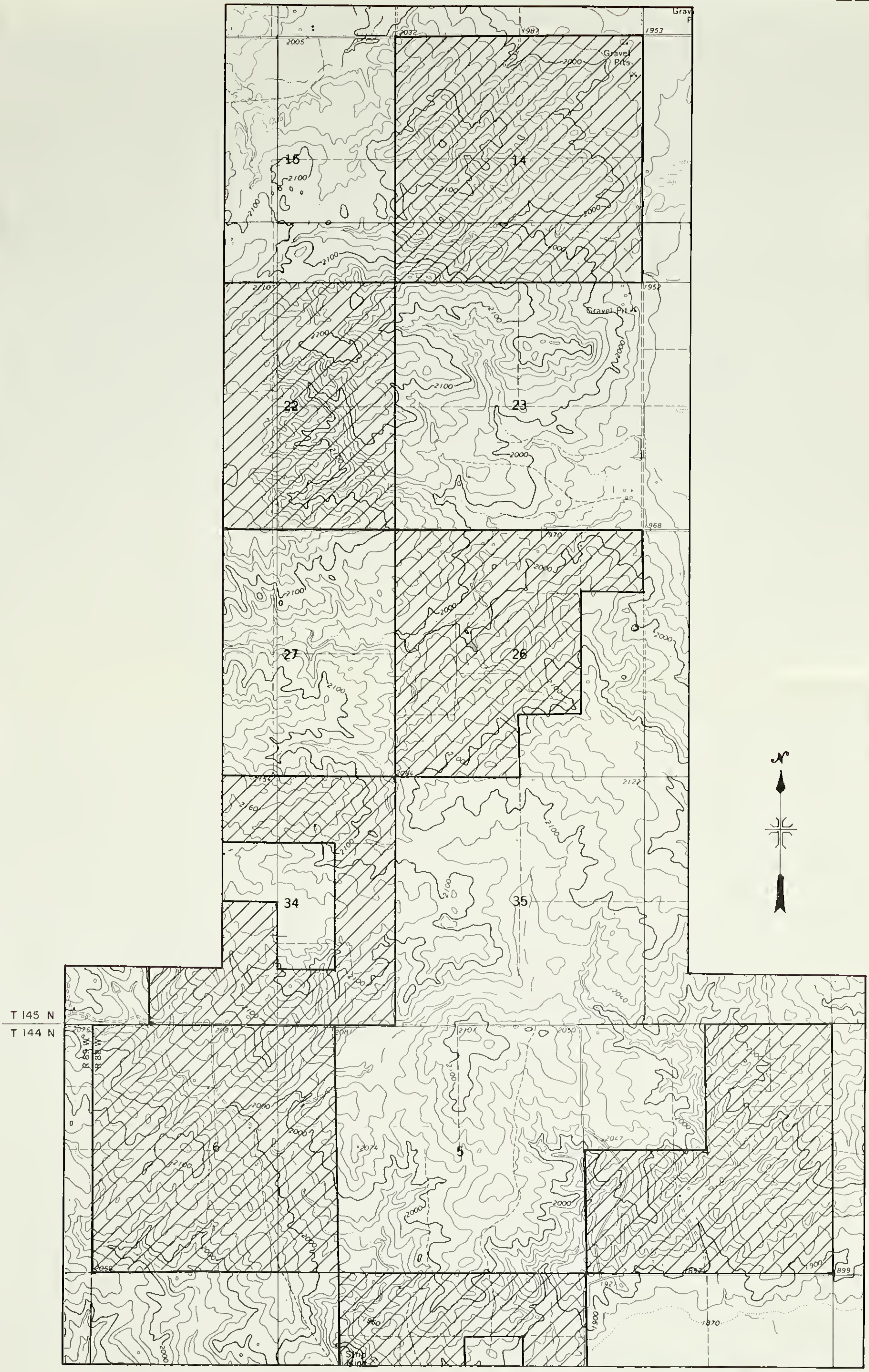
MULTIPLY FEET BY 0.3048 TO OBTAIN METERS

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD

TOPOGRAPHY

Plate 2

Note: Study area not shaded



MINERALS OWNED BY THE FEDERAL GOVERNMENT

COAL ONLY

ALL SURFACE AREA EXCEPT SEC. 36, IS PRIVATELY OWNED. SEC. 36 IS STATE OWNED.

0 2000 4000 6000 8000 FEET

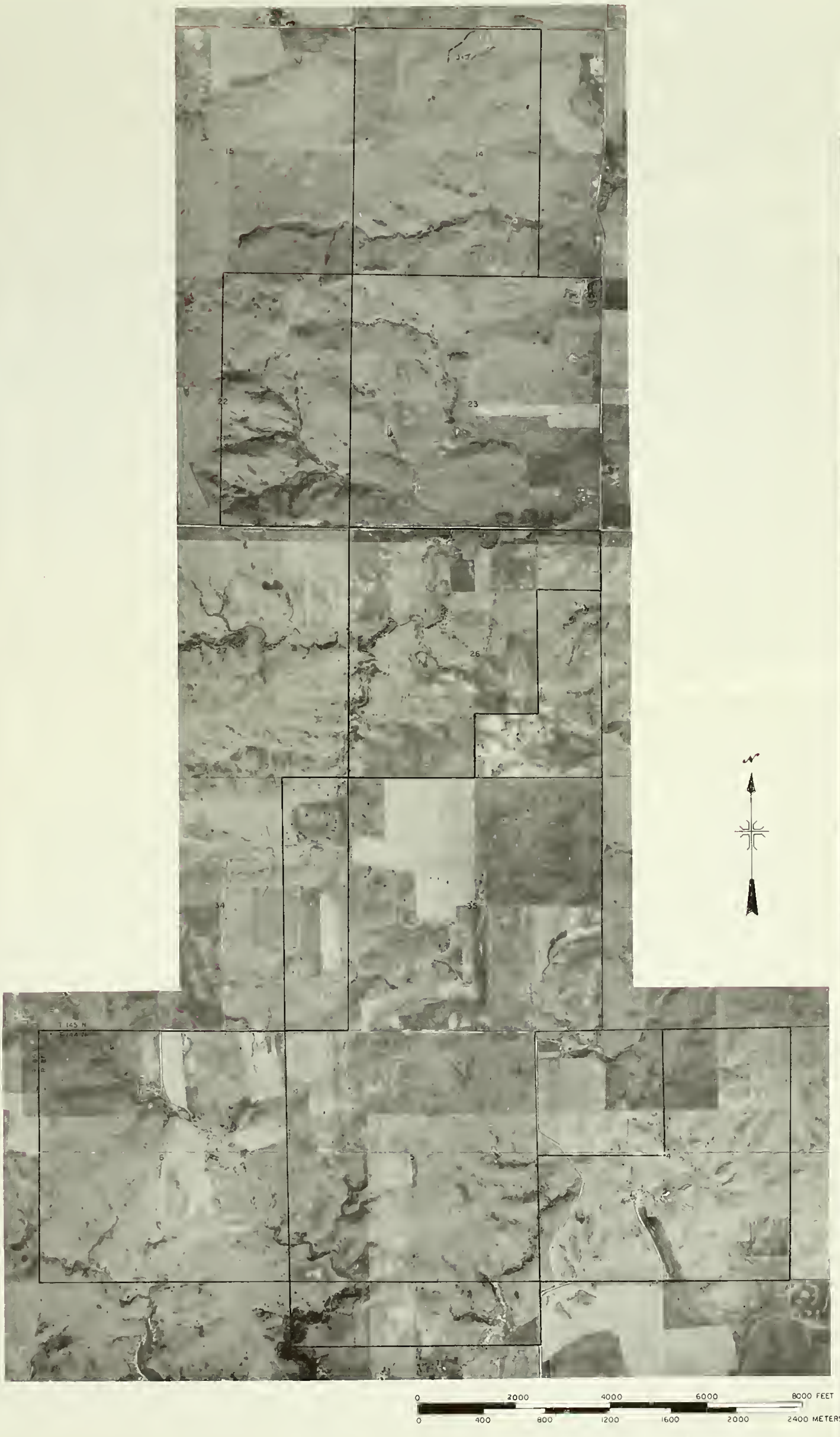
0 400 800 1200 1600 2000 2400 METERS

CONTOUR INTERVAL – 20 FEET
MULTIPLY FEET BY 0.3048 TO OBTAIN METERS

RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD

MINERAL STATUS MAP

Plate 3



RESOURCE & POTENTIAL RECLAMATION EVALUATION
BEULAH TRENCH STUDY AREA
WEST RENNERS COVE COALFIELD
AERIAL PHOTOGRAPH

Photograph 1

GEOLOGY

Geologic investigations of the study area included mapping the surface geology and drilling 12 holes ranging from 90.2 to 279 feet deep. Continuous cores were obtained from all holes for geologic logging and for the selection of coal and overburden samples for laboratory analyses.

The study area lies in a part of the Williston Basin known as the West Renners Cove Lignite Field. Bedrock is of Paleocene Age and belongs to the Sentinel Butte Member of the Fort Union Formation. It is mostly soft shale and sandstone with lesser amounts of siltstone and lignite.

Six persistent lignite and/or lignitic shale beds were penetrated by drilling in the area. Probably only one, the Beulah-Zap coalbed, is of economic significance. It averages about 20.4 feet thick and is usually covered by less than 200 feet of overburden.

Engineering property tests conducted on bedrock samples similar to the material at the Beulah Trench Study Area have revealed that shear strengths are low, especially in a saturated condition. Slides can easily develop adjacent to high walls in surface mines, primarily along beds of weak, plastic, carbonaceous shales. Saturated alluvial deposits and uncemented siltstones and fine grained sandstones will readily erode and flow into excavations.

Excavation slopes will vary between minesites and will be dependent on exposure time, moisture conditions, material types, and depth of cut. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden, and excavation below the water table will be limited until the material is drained.

Studies of similar material at other EMRIA sites indicate that disturbed overburden should have slopes not greater than 4 to 1 and berms of 50 to 100 feet in width designed on the slope surface.

Volume changes in the overburden will occur with disturbance. An increase in volume of about 25 percent should be expected. In some cases, the surface of the replaced overburden will be higher after mining.

Three types of instability are common on reclaimed coal-mined areas in the Northern Great Plains. They are: 1) areawide settling, 2) localized collapse, and 3) piping. Each form of instability is affected by certain variables in the postmining landscape. These variables include the physical and chemical characteristics of the overburden, the methods and equipment used in stripping and contouring operations, and the season when these activities occur. One or more of these types of landscape instability may occur on reclaimed land in the Beulah Trench Study Area.

Weathering tests performed on bedrock samples from the study area revealed that shales break down more rapidly than either sandstones or siltstones, but the material produced may be difficult to place and handle due to its plastic nature.

Most types of earth materials suitable for construction are available in the study area. Only concrete aggregate and high quality riprap material will probably have to be obtained from outside the study area.

A study of the seismic history of the region indicates that the Beulah Trench Study Area is stable and can expect no significant earthquake damage.

COAL RESOURCES

The Beulah Trench Study Area, about 5 square miles in size, is located in the West Renners Cove Coalfield, in the Sentinel Butte Member of the Fort Union Formation.

Lignite beds within 300 feet of the surface were evaluated by 12 core holes. Lignite resources--measured, indicated, and inferred--within the study area are 30,903,000 short tons, 74,264,000 short tons, and 4,750,000 short tons respectively.

The heat of combustion (moist, mineral-matter-free basis) for 24 samples from the Beulah Trench Study Area ranged from 6,990 Btu/lb to 7,840 Btu/lb. The apparent rank for all samples is lignite A.

A comparison of the data from the 24 Beulah Trench lignite samples with data from 32 other Fort Union region lignite samples show that the Beulah Trench Study Area lignite has significantly higher contents of sulfate and organic sulfur. Contents of moisture, volatile matter, fixed carbon, ash, hydrogen, carbon, nitrogen, oxygen, total sulfur, pyritic sulfur, and heat of combustion are not significantly different.

OVERBURDEN - SOIL AND BEDROCK

PRINCIPAL SOIL BODIES

Soils of the Beulah Trench Study Area can be grouped into three major categories based on their parent material, mode of development, and land form position. They are: 1) residual soils developed over soft sandstone, siltstone, or shale which occur on gentle to steeply sloping uplands; 2) glacial soils occurring in uplands on morainal ridges and rounded, gently sloping hills; and 3) alluvial and colluvial soils located along intermittent streams and on lower footslopes and fans at major changes in surface gradient. All soils in this study area show surface layers relatively high in organic matter content, owing to their development under a cool mid-grass type vegetation.

Residual Soils

Residual soils occupy about 58 percent of the study area. Slopes range from 3 to 35 percent on tracts occupied by these soils. Depth of the soil solum (A and B horizons) is largely slope-dependent, with shallow soils (4 to 18 inches) occupying steeper slopes and deeper soils (often exceeding 40 inches in depth) occurring on gentle sideslopes and ridges.

The surface layer of the residual soils is a friable, noncalcareous, grayish brown to dark grayish brown sandy loam to clay loam. The subsurface layer is typically a calcareous clay loam. Water readily infiltrates these soils and percolates freely through the surface horizon. However, downward movement of moisture is often restricted in the fine-textured subsurface horizons.

A few localized tracts of residual soil, usually less than 4 acres in size, have developed over baked rock (clinker). These soils are nonsaline, nonsodic, permeable, and retain about 1.5 inches of plant-available moisture per foot.

Glacial Soils

Glacial soils occupy nearly 33 percent of the study area. Slopes range from 3 to 15 percent on lands occupied by these soils. The depth of the soil is largely slope-dependent, ranging from less than 48 inches to over 10 feet.

The surface layer of these soils is typically a dark grayish brown loam, 4 to 18 inches thick. The subsurface layer is commonly a grayish brown clay loam, 18 to 48 inches in thickness. The soil profile is permeable to this depth. It is also noncalcareous and retains about 2 inches of available moisture per foot. The subsoil consists of light brownish gray or light yellowish brown clay loam till material. It is calcareous and has slow to moderate permeability.

Alluvial and Colluvial Soils

Alluvial and colluvial soils occupy about 9 percent of the study area. These soils are quite similar in appearance since both consist of local material transported short distances by water. They occur primarily on fans, footslopes, and along intermittent drainages. Depth of the soil ranges from 3 to 10 feet.

The surface layer of the colluvial soils is typically a dark grayish brown, friable loam. This layer is nonsaline, nonsodic, permeable, and retains about 2 inches per foot of available moisture. The subsurface layers are grayish brown to brown and friable. Textures range from sandy clay loam to clay loam.

The surface horizon of the alluvial soils is commonly a very friable, dark gray fine sandy loam. It is nonsaline, nonsodic, and noncalcareous. The subsurface horizons consist of light grayish brown clay loam with randomly interspersed layers (1 to 2 inches thick) of sandy material. These subsurface horizons are nonsaline, nonsodic, and moderately to strong calcareous. The available moisture retained in these soils is approximately 2.2 inches per foot.

LAND SUITABILITY SURVEY

A detailed land suitability survey was made to determine the suitability of overburden (soil and bedrock) materials for use in revegetating the study

area if it is surface-mined. Land suitability specifications were developed specifically for use in this study area. Field and laboratory data were used to evaluate the quantity and quality of materials in the soil mantle and bedrock.

Four land classes, 1, 2, 3, and 6, were established to group land of equal suitability for the specific use of revegetation. Class 1 lands provide the most desirable and plentiful source of easily stripped revegetative material. Land in this class may have surplus suitable material that can be utilized in deficient areas. Class 2 lands have adequate resurfacing material, but of lower quality and more difficult to strip than Class 1 lands. Class 3 lands are marginally suitable, but can meet the planting media needs for their revegetation. Class 6 lands are deficient in adequate suitable material; therefore, it will be necessary to borrow suitable material from adjacent lands or modify the available material in order to meet the needs for revegetation.

The results of the land suitability survey of the Beulah Trench Study Area expressed as a percentage of the area are as follows: Class 1 - 43.6; Class 2 - 33.2; Class 3 - 21.5; and Class 6 - 1.7.

OVERBURDEN SUITABILITY

Soil Mantle Suitability

In general, the deep residual, glacial, and alluvial/colluvial soils in this study area should provide an adequate supply of good quality topsoiling material for revegetation. The A and B horizons of most soils in this area are nonsaline, nonsodic, and permeable. In many cases, these horizons may be mixed without an appreciable change in the quality of the material.

Local tracts of clay-rich, saline, or saline-sodic soils will require borrowed material from nearby areas with abundant, good quality material or from suitable bedrock, if readily available in the area.

Bedrock Suitability

Similar criteria were used for the land suitability survey and the bedrock core evaluation in the Beulah Trench Study Area. However, different suitability classes were assigned to the bedrock materials. These classes relate primarily to the quality of the bedrock materials for use as plant media in revegetation. The suitable class is roughly equivalent to Class 1 and the best Class 2 materials in the Land Suitability Survey; limited suitability corresponds to the less desirable Class 2 materials and Class 3; and unsuitable is equivalent to Class 6.

Based on the results of laboratory analyses, 24 percent of the bedrock materials overlying the Beulah-Zap coalbed in this study area were determined to be suitable for use as plant media, 29 percent were of limited suitability, and 47 percent were unsuitable.

Notable deficiencies of those bedrock materials placed in the limited suitability or unsuitable classes often included: salinity, sodicity, fine texture (clay-rich), slow permeability, and/or erodibility.

SOIL INVENTORY

This section was incorporated into the main report in order to provide additional data on the soils occurring in the Beulah Trench Study Area. The main source of the information presented in this section was the Soil Survey of Mercer County, North Dakota (USDA - Soil Conservation Service, 1978).

The following data is included in the main report:

1. A Soil Inventory Map of the Beulah Trench Study Area showing the soil series/associations mapped by the Soil Conservation Service.

2. Soil Series Descriptions (National Cooperative Soil Survey).

3. Interpretations for Selected Soil Uses.

4. Engineering Measurements of the Soils.

5. Soil Profile Descriptions (BLM Form 7310-9) and Erosion Evaluations (BLM Form 7310-12).

MOISTURE RELATIONS IN SOILS

Availability of soil moisture to the vegetation is controlled by moisture-retention capability, which is a function of soil texture and humus content, and by void-moisture capacity, which is a function of bulk density. The natural soils of the study area have sufficient void space near the surface to allow infiltration and drainage to the rooting depth. In most of the soils, there is a constriction in the void space below the root zone which impedes drainage and makes the moisture more readily available to vegetation. This condition favors the occurrence of midgrasses and tallgrasses, which are more productive than shortgrasses. At the base of the profiles, there is usually a reserve of moisture available to the vegetation that apparently is unused except during droughts.

In reconstructing soils after mining, it would be most advantageous to reposition the humic surface soils back on the surface. Humic soils retain their void capacities well because they are more resistant to compaction than nonhumic subsoils. The nonhumic subsoils should be repositioned below the humic topsoils and compacted so that drainage will be constricted. Sufficient depths of topsoils must be used to prevent the formation of water tables above the constrictions. Salts would rise from the water tables into the topsoils and be detrimental to the vegetation.

GREENHOUSE

The objectives of this experiment were twofold:

1. Characterize soil and bedrock strata through greenhouse studies relating to revegetation of surface-mined lands, and

2. Conduct soil and plant analyses of selected materials for identifying potential problems relating to toxicity and/or nutrient deficiencies that may limit plant growth.

Western wheatgrass was chosen as the primary test species because it is one of the most abundant native species in the western United States and will probably be used in many revegetation programs.

Based on the results of soil and plant analyses and calculation of relative yields, the soil and bedrock samples were assigned ratings of suitable, questionable, or unsuitable for use as plant media.

The soil samples were rated 38 percent suitable, 33 percent questionable, and 29 percent unsuitable. Twelve percent of the bedrock samples were rated suitable, 21 percent were questionable, and 67 percent were unsuitable.

Salinity and/or sodicity problems appeared to be the major limiting factors for most of the materials classed as unsuitable.

VEGETATION

The richness of the flora in Beulah Trench Study Area is indicated by the fact that some 62 species were sampled, including 5 shrubs, 22 grasses, and 35 forbs. A complete species list would have shown many more species to be present.

In general, the pastures have been heavily grazed for many years and this has caused range conditions to decline. Estimates of range condition varied from a low of 33 percent of climax (fair) to 59 percent (good) with an average of 48 percent or high fair condition. All of the sampled ungrazed areas adjacent to pastures were in excellent condition.

For mapping purposes, the vegetation was arranged into three general categories as related to topography: 1) relatively flat areas (Needleandthread-Blue grama), 2) sloping areas (Prairie sandreed-Little bluestem), and 3) relatively flat alluvium or flood plains (Western snowberry-Prairie sandreed). The names of these groups were derived from the vegetation on ungrazed areas which represents potential vegetation for the study area.

Productivity similar to or greater than that of the present potential vegetation is a feasible objective for reclamation following mining.

HYDROLOGY

Ground Water

Stripping of overburden and removal of coal would result in temporarily increased discharge from the lignite and other shallow aquifers. Recharge to the shallow water-table aquifers in overburden is from direct infiltration of precipitation. Recharge to the lignite aquifers is from downward leakage from shallower aquifers. In areas of thick bedrock and glacial till cover, recharge and vertical movement of precipitation to the lignite aquifer is very slow. This fact coupled with the increased water withdrawals at a mine site could temporarily lower water levels drastically in areas upgradient from a new mine site. However, the apparent low permeability of the lignite and clay-silt bedrock of the Sentinel Butte may reduce or at least delay the decline in water levels at large distances

away from a proposed mine site. It is reasonable to assume that large declines in water levels in wells in lignite and shallower aquifers would not extend more than 1 to 2 miles from an active mine site.

Water levels in deeper aquifers would not be adversely affected, as the heads are lower in progressively deeper aquifers. However, mining and dewatering of shallow aquifers should result in changes in hydraulic gradients and a reduction in local recharge to aquifers beneath the Beulah-Zap lignite.

If a normal dragline procedure is used to remove overburden, replacement of material is in reverse order of the original state. Thus, sediments that are high in soluble and exchangeable sodium would be deposited near the surface in an environment of rapid oxidation and alteration. Available pyrite would be quickly oxidized; however, the resulting acidity would probably be buffered by solution of carbonate minerals and subsequent cation exchange of divalent cations for sodium. Resultant leachate from spoil piles should then have high concentrations of sodium, bicarbonate, and sulfate, and lower concentrations of calcium and magnesium.

Leachate and ground water flowing into mine pits from exposed aquifers may be expected to contain more dissolved material than normal ground or surface waters. Therefore, shallow ground water beneath mine sites may increase in dissolved solids concentration. If mine sites are located at or near the edge of the Antelope Creek aquifer, it seems probable that shallow ground water in areas of the aquifer that are below the mine sites will deteriorate with time.

The available geochemical and hydrologic data of the Sentinel Butte and Antelope Creek aquifers would indicate that small local plumes of water rich in sodium and sulfate could result from mining along the edge of the valley. Water samples from shallow areas in reclaimed spoils at Gascoyne, North Dakota (Croft, oral commun., 1978), were strong sodium sulfate waters with total dissolved solids as high as 24,000 mg/L.

Present hydrologic data indicate that parts of the Antelope Creek aquifer which lie in T. 145 N., R. 88 W., sections 13 and 24, are major recharge areas for the upper Antelope Creek unit. Effluent from strip pits or runoff from rain and snow which infiltrates through spoils could easily move into the shallow ground water system in these areas. An extensive unit of fine-grained sediment that divides the aquifer into upper and lower units may prevent the transport of solute to the lower aquifer unit.

The potential for contamination of ground water with toxic levels of trace metals would be very small. Solution and transport of toxic organics derived from coal, however, could present a serious problem; but, few studies on this topic have been made.

Further geochemical studies are necessary to make accurate predictions of the potential for an increase in concentration and transport of any given chemical species from a mine site to potable ground water supplies.

Surface Water

The impacts of mining on the quantity and timing of runoff will be dependent on mining practices but will probably be very minor. There could be some

realignment of small tributaries of the main streams, but the overall drainage area should remain essentially unchanged. Alteration of existing stream channels within the mining area to intercept and divert surface runoff could cause alterations in the existing flow regimen downstream. As spoils or reclaimed areas probably will, at least initially, have greater infiltration capacity than undisturbed material, there would be decrease in runoff from snowmelt or rainfall events. There is the possibility, with the increased infiltration, of the development of springs and consequent temporal extension of base flow in the streams. The overall flow regimen of Antelope Creek tributary will probably be altered only slightly unless there are deliberate impoundments or other alterations on the same mainstream.

There should be little change in the chemical quality of water diverted around the active mining areas. However, runoff from the spoils and(or) reclaimed areas will probably show increased salinity. Recharge to the streams will be affected by increased infiltration in spoils, and reclaimed land could be expected to have a high salinity.

Hydrologic Classification of Land Types Using Rainfall Simulation

Simulated rainfall at an intensity of about 2 inches per hour was applied to four very small watersheds, about 2300 to 2700 square feet in area. Runoff volumes varied from very low to moderate. Sediment yields were all low, but they varied somewhat.

Both runoff and sediment yield were inversely related to the root contents and bulk densities of the surface soils. Lowest runoff and sediment yield were from the only site underlain by clinker (baked rock), even though the site was on the steepest slope. A site with nearly the highest runoff and sediment yield had the greatest clay amount, and the vegetation showed effects of prolonged overgrazing.

Sediment Yields

Sediment yields from the study area are presently quite low. Good conservation practices, a highly organic surface soil, and an excellent vegetative cover have all contributed to the soil retention effort. Other than some rilling in cultivated fields, erosion is no problem. This stable condition will, however, change with mining.

During mining, the outer slopes of raw, ungraded spoils would be expected to yield sediment at rates of perhaps 10 or more times greater than those presently estimated for the study area. For areas being returned to rangeland, sediment yield rates perhaps will be 2 to 5 times greater than rates from present rangeland during the first 4 or 5 years of the rehabilitation period after reshaping, topsoiling, and seeding of adapted grasses. After this period and when the vegetation is fully established, water-stable soil aggregation and soil voids have reestablished, and the channels have stabilized, sediment yield rates should approximate the present rates. Sediment yield rates from areas returned to cropland will also be greater than present rates until probable compaction is worked out of the soil and soil aggregation is reestablished. After that time, the sediment yield rates from cropland should approximate present rates.

RECOMMENDATIONS FOR RECLAMATION

INTRODUCTION

Should surface mining occur in the Beulah Trench Study Area, the coal mine operator will be required to restore all disturbed areas "in a timely manner to conditions that are capable of supporting the uses which they are capable of supporting before mining, or to higher or better uses . . ." (Chapter 38-14.1, Section 69-05.2-23-01, North Dakota Century Code).

Unless an alternative postmining land use is desired by the landowner(s) and approved by the North Dakota Public Service Commission, the main objective of reclamation will be to restore the mined land to a condition capable of supporting the uses that it supports today. These uses are rangeland, hayland, and cropland (small grains).

STABILITY OF THE POSTMINING LANDSCAPE [2/]

The design of a stable postmining landscape in the Beulah Trench Study Area will require the integration of several critical factors: These include: 1) a detailed knowledge of the distribution of overburden materials, with emphasis on the delineation of highly sodic spoils, 2) proper equipment selection, and 3) a consideration of seasonal factors. For reclamation to be successful, consideration must be given to the entire landscape, not merely the soil zone.

Three forms of landscape instability are common on reclaimed coal-mined areas in the Northern Great Plains. These are areawide settling, local collapse, and piping.

Areawide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This form of subsidence will probably be most pronounced during the first year following reclamation and will continue at a decreasing rate for a number of years. The two major factors influencing areawide settling are: 1) texture of the overburden, and 2) equipment used in spoil contouring operations.

A significant quantity of overburden in the Beulah Trench Study Area consists of fine-textured material (shale). When disturbed, this material usually results in more blocky and, initially, more porous spoils than does coarse-textured overburden (sandstone). Therefore, a greater degree of areawide settling may be expected in this area as compared to an area where coarse-textured materials are predominant.

Equipment used in contouring operations is a critical factor influencing areawide settling. Settlement is significantly less in scraper-countoured areas than in dozer-contoured areas due to the fact that scrapers more

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2/ Groenwold, G.H. and Rehm, B.W., 1980 (modified)

effectively break down large overburden blocks and compact the spoil mass. Therefore, the degree of areawide settlement may be reduced by employing scrapers rather than dozers in spoil contouring operations.

Local large-scale collapse often develops soon after contouring is completed. Development typically ends within 1 year. This form of instability is predominant in precontouring valleys where large, frozen spoil blocks are concentrated by mid-winter dozer contouring. Thawing of these blocks results in local surface subsidence. To restrict the development of local collapse features, the use of scrapers rather than dozers should be considered for contouring operations during the winter months.

Piping appears to be a severe and long-term problem in some postmining landscapes. This form of instability usually begins soon after contouring ceases and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years.

Piping is apparently controlled by a combination of physical and chemical conditions in the spoils. All piping begins as a crack, either on the surface of exposed spoils or at the topsoil-spoil interface. In the latter case, the overlying topsoil collapses into the pipe and is carried away. Repeated topsoil application is usually unsuccessful in stopping the growth and development of piping. Cracking of spoils is restricted to areas of highly dispersive sodic materials. The cracks allow access for large volumes of surface runoff to flow into the subsurface of the spoils. However, surface cracking alone will not necessarily result in the development of piping. Piping will develop only if an avenue for water movement can result from fracturing within the mass of spoils due to settling between differentially compacted areas (i.e., scraper-contoured area adjacent to dozer-contoured area) or within areas of poorly compacted spoils (i.e., dozer contouring only).

Piping usually develops in nearly flat areas, where runoff is minimal and infiltration is maximized. Thus, the final surface slopes in reclaimed areas must also be recognized as controlling factors in the development of piping.

Given the proper conditions of slope, near-surface dispersive materials, and a permeable zone in the base of the spoils, piping may continue to develop and disrupt the restored landscape for many years. Selective placement of excessively sodic overburden encountered in this study area may prove to be the only effective means of controlling piping.

Because the postmining landscape in the Beulah Trench Study Area will be unstable, structures should not be built unless they are specifically designed to absorb differential settlement. Also, reconstructed drainage channels will require periodic maintenance to ensure that ponded areas do not develop in areas of localized settling.

GRADING AND HANDLING OF SPOIL MATERIALS

Mine operators will be required by law to grade all disturbed areas "to the gentlest topography consistent with adjacent unmined landscape elements . . . ." All spoil shall be transported, backfilled, compacted

(where advisable to insure stability or to prevent leaching), and graded to eliminate all highwalls, spoil piles, and depressions (Chapter 38-14.1, Section 69-05.2-21-01(2)(a), North Dakota Century Code).

Where possible, all final grading and preparation of graded land prior to the redistribution of topsoil should be conducted along the contour to minimize erosion and maximize landscape stability.

Present North Dakota law states: "Spoil materials that are found by the (Public Service) Commission to be excessively saline, sodic, or both, are considered to be toxic-forming materials and shall be covered with a minimum of 4 feet of nontoxic material, provided such material is available" (Chapter 38-14.1, Section 69-05.2-21-03(1), North Dakota Century Code). Based on the results of laboratory tests performed on samples from 11 drill holes in the Beulah Trench Study Area (see Tables 30 through 45, Appendix E), it appears as though a significant number of the bedrock strata are excessively sodic. However, these materials generally underlie at least 40 feet of nontoxic overburden. Therefore, an adequate quantity of nontoxic soil and bedrock should be available to sufficiently bury the sodic spoils. Highly sodic spoils should not be buried in proximity to a drainage course where they may pose a threat of water pollution.

EROSION CONTROL

Reducing runoff and erosion and increasing the on-site conservation of moisture for vegetative establishment are feasible objectives for reclaimed land in the Beulah Trench Study Area. The following procedure is recommended as a means toward achieving these objectives: 1) reduce the mean surface slope in the reclaimed area, 2) scarify the surface of the regraded spoils, 3) replace the subsoil/topsoil and prepare a seedbed, 4) conduct seeding and planting operations as soon as possible after topsoil redistribution, and 5) apply mulch to the newly seeded areas.

Reducing the mean surface slope in the reclaimed area will provide a more gently sloping landscape. A more level landscape will allow for an increase in infiltration and moisture retention and a decrease in runoff and sediment yield. The increase in moisture retention will be highly desirable for seedling establishment in the reclaimed area.

Prior to the redistribution of suitable plant growth material, the surface of the regraded spoils should be ripped or chiseled in order to 1) eliminate slippage surfaces at the spoil-topsoil interface, and 2) provide a favorable subsurface medium for air/water infiltration and root penetration. Ripping or chiseling should be conducted along the contour wherever possible to prevent runoff and ensure maximum stability.

Subsoil and topsoil are often compacted by heavy machinery during the redistribution process. These materials should be loosened by chiseling or other means prior to actual seedbed preparation (disking/harrowing). The loosened material will allow roots to readily penetrate its matrix and will also facilitate a higher rate of air/water infiltration. All tillage operations should be conducted along the contour to prevent excess runoff and substantial loss of the plant growth material.

Seeding and/or planting should be conducted as soon as possible after the topsoil has been spread and a seedbed has been prepared. The establishment of a permanent vegetative cover as quickly as possible will be the most effective method of controlling erosion in the reclaimed area. A temporary cover of small grains, grasses, or legumes may be required to protect the topsoil until such time as a permanent cover can be established.

Suitable mulch should be applied on all newly seeded areas to control erosion, conserve soil moisture, and enhance seed germination. For the Beulah Trench Study Area, consideration should be given to the use of 1) hay or straw mulch applied at a rate of about 2 tons/acre, or 2) an "in situ mulch" of standing stubble from spring planted small grains. If hay or straw mulch is applied, it should be anchored (disked or "crimped") to the soil surface to prevent substantial losses of the material due to blowing.

REVEGETATION

Revegetation of surface-mined land in the Beulah Trench Study Area will require: 1) removal, segregation, and redistribution of suitable plant growth material, 2) selection of adapted plant species, and 3) use of proper planting and seedbed preparation procedures.

Removal, Segregation, and Redistribution of Suitable Plant Growth Material

Prior to the actual mining operation, all suitable plant growth material should be removed and either redistributed immediately on regraded areas or segregated in separate stockpiles.

North Dakota regulations require that both topsoil and subsoil be salvaged for replacement as plant media (Chapter 38-14.1, Section 69-95.2-15-02(2), North Dakota Century Code). This is accomplished in a 2-lift process with the most desirable plant growth material ("topsoil") being removed in the first lift and the remaining suitable material ("subsoil") being salvaged in the second lift. Based on the results of the Land Suitability Survey included in this report, it appears that a minimum of 12 inches of good quality topsoil can be removed in the first lift from most soils in the study area. This material is typically nonsaline and nonsodic, permeable, and contains a moderate amount of organic matter. The depth and quality of subsoil material in this study area is highly variable.

If stockpiling of the suitable plant growth material is necessary, the stockpiles should be selectively placed on a stable area and protected from erosion, compaction and contaminants (toxic spoils). Establishment of a quick growing vegetative cover on the stockpiles is probably the most effective method of protection; however, other measures such as snow fences, mulches, or chemical binders may also be considered.

Before the suitable plant growth material is redistributed, the regraded land should be scarified (ripped) to eliminate slippage surfaces and enhance root penetration. The redistribution of subsoil and topsoil, respectively, should then proceed in a manner that achieves an approximate uniform thickness consistent with the postmining land use(s) and prevents excess compaction of the spoils and suitable plant growth material.

Finally, nutrients (fertilizer) and soil amendments should be added to the surface soil layer in the amounts determined by soil tests. All soil analyses should be performed by a qualified laboratory using procedures approved by the Public Service Commission (North Dakota).

Selection of Adapted Plants

To comply with established State regulations, the mine operator will be required to establish on all disturbed areas a "diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area. . ." (Chapter 38-14.1, Section 69-05.2-22-01, North Dakota Century Code). Introduced species may be substituted for native species only if appropriate field trials have demonstrated that the introduced species are of equal or superior utility for the approved postmining land use(s), or are necessary to achieve a quick, temporary, and stabilizing cover. The Public Service Commission must approve the use of introduced species.

Some important considerations in selecting revegetative species for the Beulah Trench Study Area should include: drought resistance, salt and sodium tolerance, resistance to winterkill, palatability, and resistance to grazing pressure. Of equal importance is plant compatibility with soil type, slope, aspect, and drainage conditions.

Table 1 lists the plants and seeding rates which are suggested for native grassland plantings, tame grass plantings (areas to be returned to cropland after 3-4 years), and salt affected soil plantings.[3/]

Seedbed Preparation and Planting

Suitable plant growth material is often compacted by heavy machinery during the redistribution process. To provide a plant medium favorable for air and water infiltration, as well as root penetration, the topsoil/subsoil should be chiseled to a depth of 18 to 24 inches prior to seedbed preparation. Disking/harrowing should then be conducted until a suitable seedbed is achieved.

Seeding of grasses and legumes with a press drill is usually the preferred technique, but good stands may also be established by broadcasting or hydroseeding. In order to provide favorable growing conditions, the seeds should be covered by 1/2 to 1 inch of soil and the surface lightly compacted to produce a good seed-soil contact.

Natural woodland complexes (woody draws) occur to a minor extent in this study area. These complexes should be avoided during the mining operation, if at all possible, as they are irreplaceable ecosystems and the majority of the prairie animal community is dependent on them. If disturbance of these complexes cannot be avoided, the trees and shrubs should be salvaged for transplanting in reconstructed drainages.

3/ From: Guidelines for Reclaiming Coal Mine Lands; North Dakota Public Service Commission, 1976.

NATIVE GRASSLAND PLANTINGS 4/

Species	Seeding Rate (lbs/acre)
Western wheatgrass	6
Pubescent wheatgrass*	1½
Little bluestem**	2
Sideouts grama	3
Green needlegrass	4
Alfalfa or	1
Sweetclover	½
Total	17-17½

* If seed not available, substitute slender wheatgrass.
** If seed not available, substitute prairie sandreed or switchgrass.

IMPROVED VARIETIES OF GRASS/LEGUME PLANTING FOR CROPLAND*

Species	Pasture or Hayland		Wildlife Planting
	Dry Site	Moist Site	
Crested wheatgrass	7	2	
Smooth bromegrass		5	
Pubescent wheatgrass**	3	3	
Intermediate wheatgrass			4
Tall wheatgrass			3
Alfalfa	1½	1½	3
Sweetclover	½	½	1
Total	12	12	11

* In pounds of seed per acre.
** If seed not available, substitute slender or intermediate wheatgrass.

SALT AFFECTED SOIL PLANTINGS

Species	Seeding Rate (lbs/acre)
Tall wheatgrass	4
Slender wheatgrass	3
Western wheatgrass	7
Sweetclover	2
Total	16

4/ Origin of native seed produced should be limited to North Dakota, South Dakota, eastern Montana, eastern Wyoming, and northern Nebraska.

Seeding and planting operations should be conducted during the first normal period for favorable planting conditions following the redistribution of suitable plant growth material. In the Beulah Trench Study Area, early spring or late fall planting of grasses and legumes appear most desirable. If spring planting is selected, the plants should be seeded between early March and late April in order that seedlings may emerge before the spring rains begin. Late fall planting should be conducted after mid-October to prevent germination. If this method is selected, consideration should be given to a light seeding of oats (10-15 lbs/acre) in August to provide stubble for erosion control and snow trapping.

POST-RECLAMATION MANAGEMENT

Responsibility of the Mine Operator

In North Dakota, the coal mine operator will be responsible for management of the reclaimed area for a minimum of 10 years. The success of revegetation will then be determined for each approved postmining land use according to the following:5/

1. For rangeland and hayland, the following requirement must be achieved for the last two consecutive years of the responsibility period:

   (a) "Ground cover and productivity . . . shall be equal to or greater than, with 90 percent statistical confidence for herbaceous vegetation and 80 percent statistical confidence for woody vegetation, the approved standard6/, and

   (b) The diversity, seasonality, and permanence of the vegetation . . . , determined from the major species and groups, shall be equivalent to that of the approved standard" (Chapter 38-14.1, Section 69-05.2-22-07(3)(a), North Dakota Century Code).

2. For cropland, "crop production . . . shall be equal to or greater than, with 90 percent statistical confidence, that of the approved standard for the last two consecutive growing seasons of the responsibility period" (Chapter 38-14.1, Section 69-05.2-22-07(3)(b), North Dakota Century Code).

On lands reclaimed to rangeland, livestock grazing "shall be practiced for at least the last 4 years of the responsibility period at a capacity approximately equal to that for similar well managed lands" (Chapter 38-14.1, Section 69-05.2-22-06, North Dakota Century Code). The Public Service Commission, in consultation with the landowner(s), will determine when the revegetated area is ready for livestock grazing.

5/ The postmining land uses in the Beulah Trench Study Area are assumed to be rangeland, hayland, and cropland (small grains).

6/ Approved standard refers to an undisturbed "reference" area chosen for comparative purposes to determine success of revegetation on the reclaimed site.

Responsibility of the Landowner

The landowners in the Beulah Trench Study Area will resume responsibility for management of the reclaimed lands following termination of the mine operator's responsibility period. To ensure that the reclaimed land remains stable and productive, the landowners should implement proper range and soil/crop management practices.

On areas returned to rangeland, grazing should be limited to a capacity that the reclaimed land is capable of supporting. Overgrazing reclaimed lands will result in a reduced vegetative cover, accelerated erosion, and an overall decrease in productivity.

On lands returned to cropland, the main objective of the landowner in cultivating the land should be sustained profitable production. To aid in achieving this objective, soil/crop management practices including contour tillage, fertilization, crop rotation, weed and insect control, mulching, etc., should be utilized whenever possible.

RESTORATION OF WATER RESOURCES

The proposed surface mining activities in the Beulah Trench Study Area will result in some restorable changes and some nonrestorable changes in the ground water, surface water, and geochemical regimes.

Ground Water

The bedrock aquifers in the sandstones above the lignite and the lignite aquifers in the mined area will be destroyed. Since it is impractical to restore these aquifers, alternative sources must be used. This would usually mean developing wells in the underlying aquifers, notably the basal sandstone unit of the Sentinel Butte Member. Some of the springs and seeps along the valley walls will be destroyed as the relatively impermeable beds causing lateral flow will be removed during mining. These cannot be restored, but their loss is not especially critical since they generally have very low yields and do not contribute much to usable water supplies.

The aquifers that lie outside the mined area in the same plane should not be disturbed except for a temporary lowering of water levels for a short distance from the mined area. In local areas it may be necessary to seek a supply from deeper aquifers. The Antelope Creek aquifer could receive increased recharge during the dewatering of the area being mined. However, some of the water would eventually have reached the aquifer by a more circuitous route.

Ground water recharge in the reclaimed area will depend on placement factors such as: postmining topography, layering and compaction of the overburden materials, postmining land use, and moisture conservation practices and(or) irrigation. The fractured state of the spoils initially could result in increased recharge to the deeper bedrock aquifers and to the Antelope Creek aquifer. As subsidence and weathering occur, the spoils should become less permeable and recharge rates will decrease. The various moisture conservation techniques will influence the amount of recharge through control of infiltration and runoff. Practices that maximize infiltration will tend to

recharge the Antelope Creek aquifer either in the proximate area of the mining or downstream.

The ground water supply in the reclaimed areas will be difficult to estimate, owing to the lenticular nature of the aquifers. Generally, adequate supplies for domestic and stock use could be obtained from the basal sandstone unit of the Sentinel Butte Member. Larger supplies of water are available from the Antelope Creek aquifer.

The shallow ground water beneath the reclaimed areas will probably show an increase in dissolved-solids concentration. It is probable that some shallow areas of the Antelope Creek aquifer could deteriorate with time. Maximum plant use could minimize the amount of water moving from the spoils into the aquifers. Dewatering in the mine areas could cause deterioration in the Antelope Creek aquifer if discharges are disposed of in the stream.

Surface Water

There should be minimal disruption of surface water use in the area. The streams are ephemeral and primary use is stock watering in ponds constructed for this purpose. The stock ponds are generally in the upper reaches of the tributaries and will not be affected by mining.

Areas of natural wetlands storage and the original water courses should be reestablished when mined land is reclaimed. Runoff characteristics can be improved to retain water for revegetation and to prevent excessive erosion. Contour furrowing, gouging, or similar land treatments can be applied to the steeper slopes. Channel areas should be reseeded to sod-forming grasses or transplanted with native sod.

Runoff water should be channeled around mine areas when possible to minimize changes in the chemical quality. Runoff from the spoils and reclaimed areas should be minimized to avoid increased salinity in the streams.

SUMMARY OF RECLAMATION POTENTIAL

Based on the resource data presented in this report, the potential for restoring surface-mined land in the Beulah Trench Study Area to a condition capable of supporting the present uses (rangeland, hayland, and cropland) appears good to excellent. The most critical factors directly influencing revegetation: 1) climate, and 2) availability of suitable plant growth material, both appear favorable in this study area.

The climatic regime in this area appears conducive to the production of native grasses and small grains. The moisture available to plants from snowmelt and spring precipitation is usually adequate for germination and establishment. Although the growing season in this area is estimated at 134 days between mid-May and mid- to late- September, the native grasses and small grains will typically mature or become dormant by about mid-July when the available soil moisture is depleted.

Most soils in this study area will yield about 12 inches of good quality topsoil which is nonsaline, nonsodic, and permeable. Given adequate moisture

and a moderate amount of fertilization, this material should provide an excellent revegetative medium. The quantity of suitable subsoil, though variable in this study area, appears adequate in most cases for reconstructing a desirable root zone.

RECLAMATION ALTERNATIVES

The present land uses in the Beulah Trench Study Area are rangeland, hayland, and cropland (small grains). Numerous alternative land uses could be considered when developing a reclamation plan for the area; however, only two alternatives appear economically feasible at the present time. These are: 1) improve rangeland/cropland productivity, and 2) convert some of the existing rangeland to cropland.

The most critical element necessary for improving rangeland and cropland productivity is additional moisture. Supplemental irrigation [7/], coupled with an intensive snow management program could provide this additional moisture. Implementation of proper range/crop management practices, i.e., limited grazing, contour furrowing, etc., would also improve productivity by controlling erosion and conserving soil moisture.

Most of the acreage in the study area is currently used for rangeland due to the rolling nature of the topography. During the reclamation process, a good opportunity will exist to convert some of this land to cropland. This would involve: 1) contouring the landscape to a more gently sloping condition conducive to cultivation, and 2) replacing the subsoil/topsoil in a rather uniform thickness over the area in order to provide an adequate rooting zone for the selected crops to be grown.

7/ Assumes that adequate ground water supplies of suitable quality could be obtained from the Antelope Creek aquifer (Beulah Trench).